Elements of Arctic climate variability and predictability

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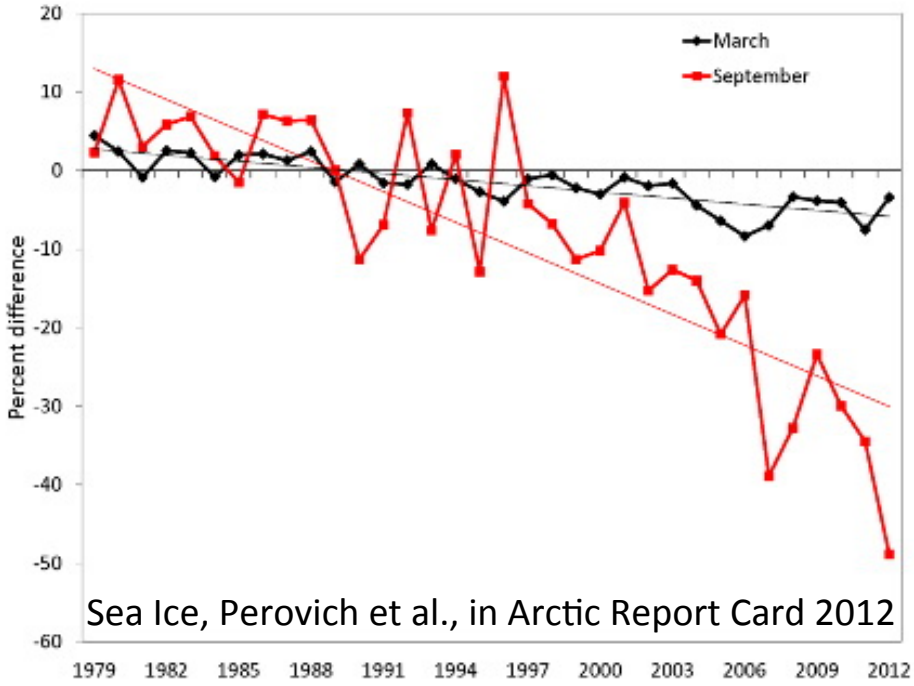
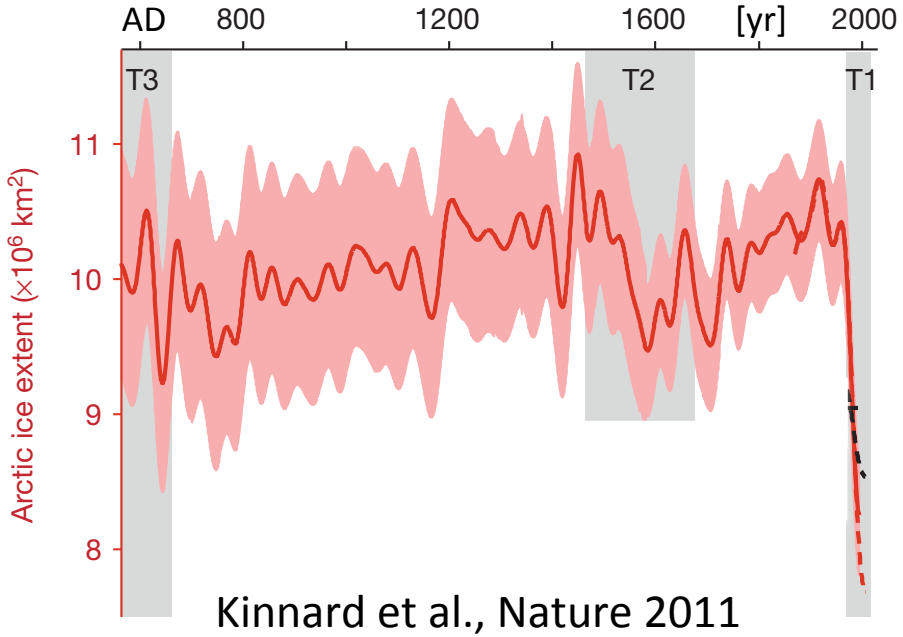


Sea Ice, Perovich et al., in Arctic Report Card 2012



Kinnard et al., Nature 2011

Institut Català de Ciències del Clima (IC3)

Catalan Institute of Climate Sciences, Barcelona, Spain

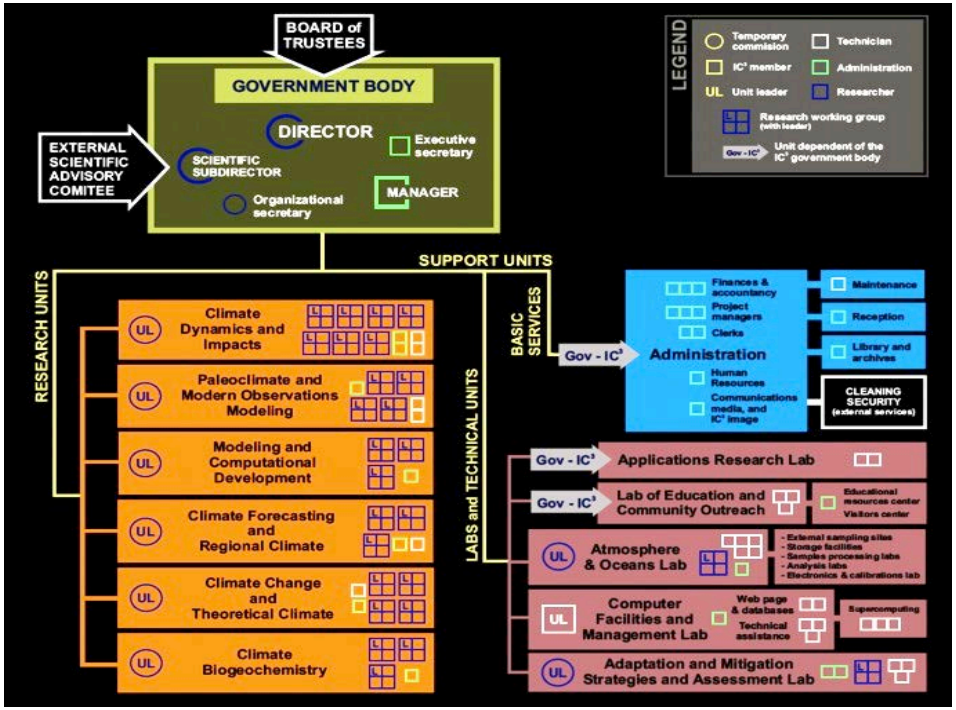
- **Climate Forecasting Unit (CFU)**

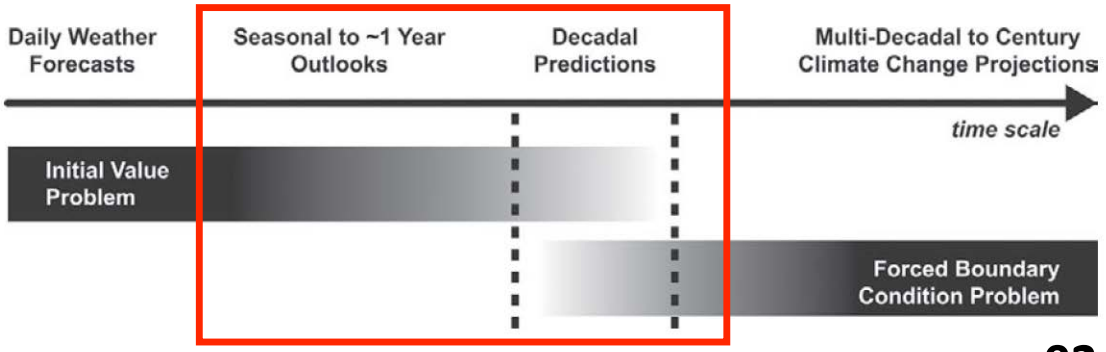
→ **22 members (from 4 continents)**

→ **External funding from 2 national and 5 EU FP7 grants**

Key objectives:

1) Advance climate dynamics
2) Development of s2d prediction capability
3) Forecast quality assessment
4) Downscaling of probabilistic forecasts
5) Climate services





http://www.ic3.cat

http://ic3.cat/wikicfu

IC3 Climate Forecasting Unit

Plans for Arctic climate dynamics and predictions

➡ **PICA-ICE** funded by Spain's MINECO :

1) Produce **sea ice reanalyses** through ocean and/or sea ice nudging

2) Study the interannual-to-decadal variability of the sea ice cover and its impact on the Northern Hemisphere climate, defining sea ice modes based on statistical **clustering methods** as an original approach

3) Assess the ability of **EC-Earth to forecast the sea ice cover** and **its impact on the European climate**

4) Perform **extreme sensitivity experiments** removing the sea ice cover to assess its recovery timescales and the large-scales impacts of such drastic change

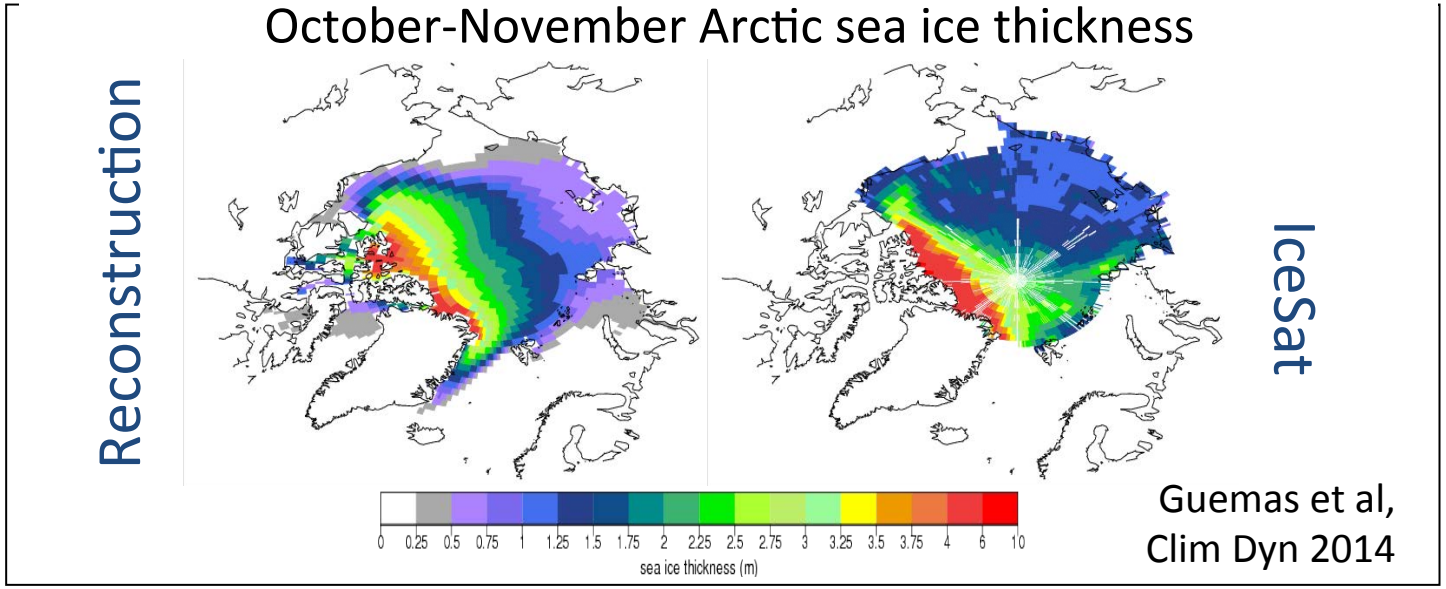
➡ **SPECS** – WP3.1 funded by European Union (FP7) :

Multi-model assessment of the **benefits of initializing the sea ice state**: best possible initial conditions versus climatological initialisation

IC3 sea ice reanalysis – NEMO3.2 simulations constrained by ocean and atmosphere obs

- **NEMO3.2 ocean model with LIM2 sea ice model**
- **Atmospheric forcings: 1958-2006 DFS4.3 and 1979-2010 ERA-interim**
- **Newtonian relaxation to ocean obs: T and S nudged towards ORAS4 reanalysis, timescales = 360 days below 800m, and 10 days above except in the mixed layer, except at the equator (1°S-1°N), SST & SSS restoring (-40W/m^2, -150 mm/day/psu)**
- **Wind perturbations + 5-member ORAS4 ⟾ 5-member sea ice reconstruction from 1958**

=> Longest available multi-member sea ice reconstruction

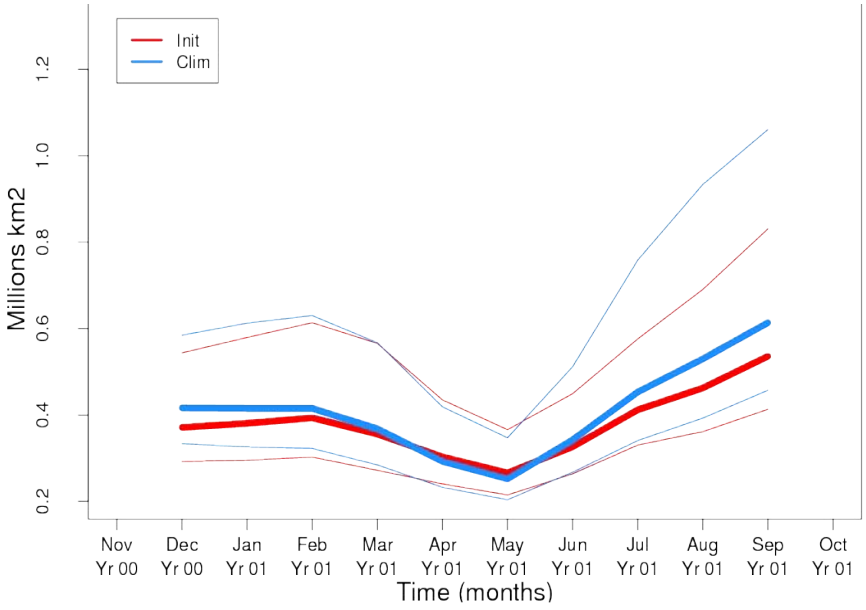


Initialisation using IC3 sea ice

- CMIP5 decadal predictions with EC-Earth2.3 started every 1st November from 1960 to 2005 also using IC3 sea ice reanalysis
  + another set of runs started from climatological sea ice IC

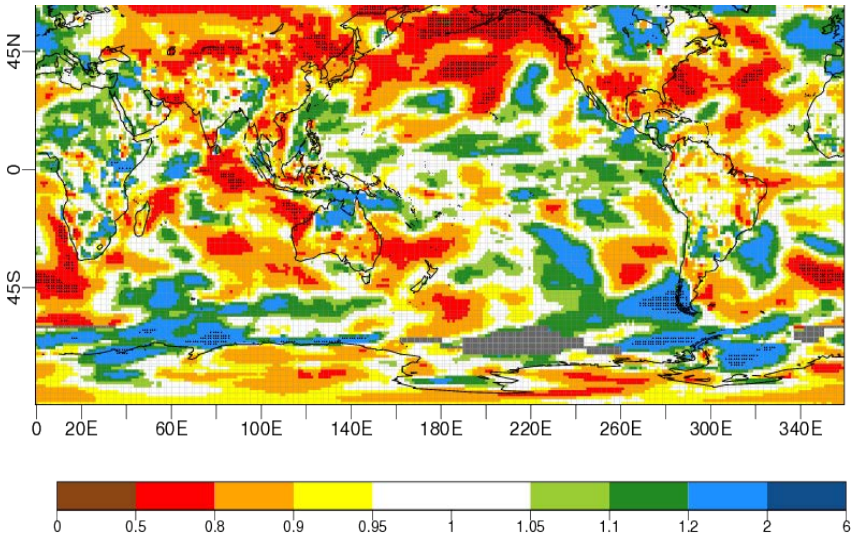
=> substantial reduction of temperature RMSE in the NH high latitudes with switch from climatology to sea ice IC from reanalysis

RMSE Arctic sea-ice area



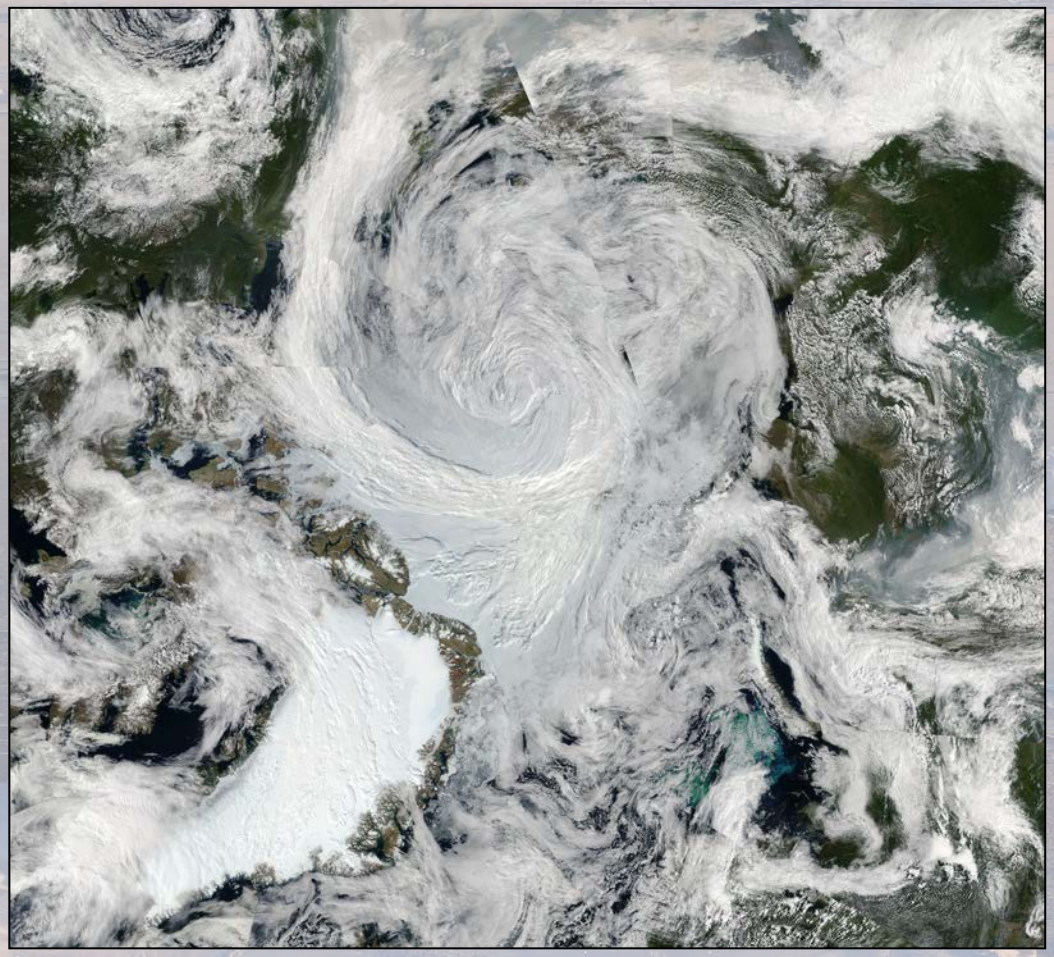
Ratio RMSE Init/RMSE Clim hindcasts two-metre temperature (months 2-4)

Guemas et al., Clim Dyn 2014



- Improved skill (higher ACC) in predicting the Arctic sea ice cover and surface air temp
- Spread between members is larger for sea ice variables, thus more representative of the forecast error

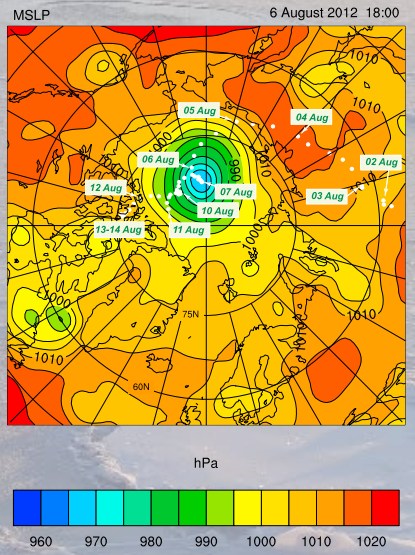
Attributing the September 2012 Arctic ice minimum



6-8 August 2012

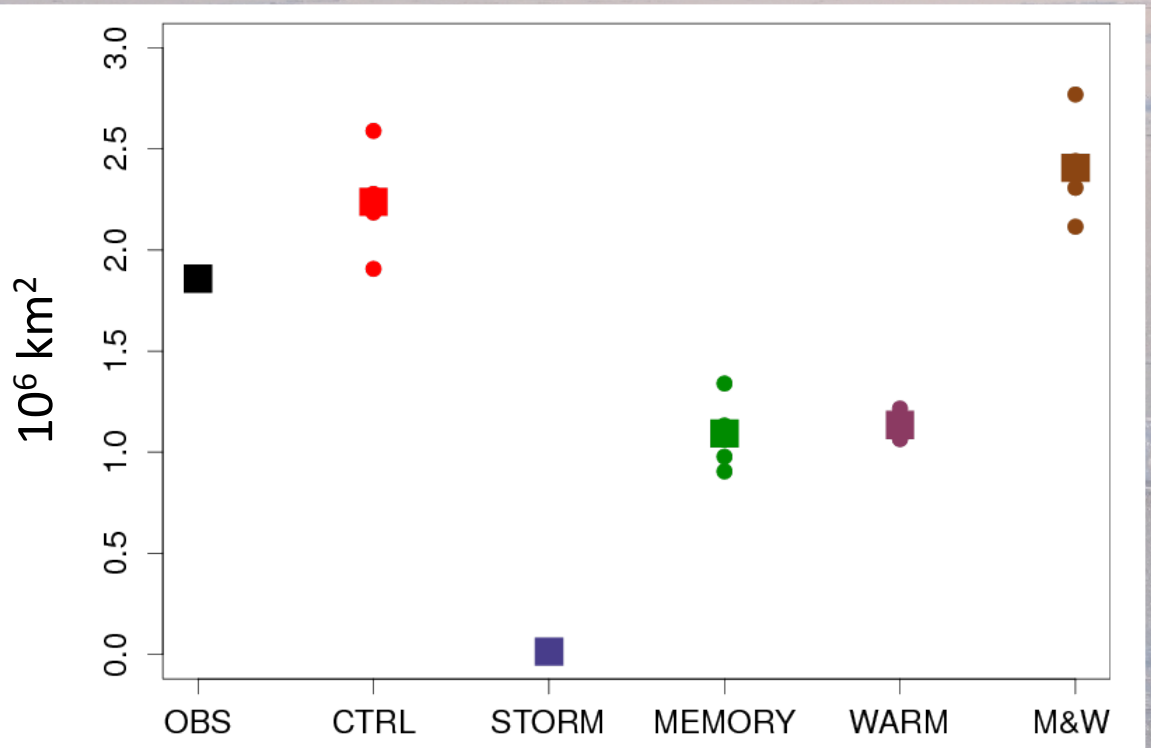
1 of the 8 most extreme summer storm over the 1979-2012 period

Simmons and Rudeva, GRL 2012



Is summer 2012 record-low sea ice extent due to weather variability, sea ice preconditioning or warm surface conditions?

Attributing the September 2012 Arctic ice minimum



Sea ice Loss relative to the average of the September minima over the 2000-2011 period

CTRL = NEMO3.2 ocean model with (LIM2 sea ice model) initialized on 1 June 2012 from a 5-member sea ice reconstruction and forced with ERA-Interim

STORM = removes the great Arctic cyclone of August 2012

MEMORY = replaces observed sea ice IC with the climatology

WARM = offset the near-surface atmospheric temperature and humidity to the average over 2000-2011 melting season

W&M = MEMORY and WARM

Guemas et al, BAMS 2013

=> 2012 record low is primarily due to sea ice IC, i.e. memory (about 50%) and warm atmospheric surface conditions (about 50%)

• K-means (nonhierarchical) cluster analysis

EOF (linear & orthogonal method) assumes symmetry between positive and negative phase. Ergo, is EOF the most suited for analysis of likely nonlinear and nonorthogonal Arctic fields?

→ Clustering method: number and spatial patterns of clusters of variability are selected to minimize variance between the member of a cluster and to maximize the variance between patterns of the different clusters

→ to identify Arctic climate regimes and their interannual-to-decadal variability

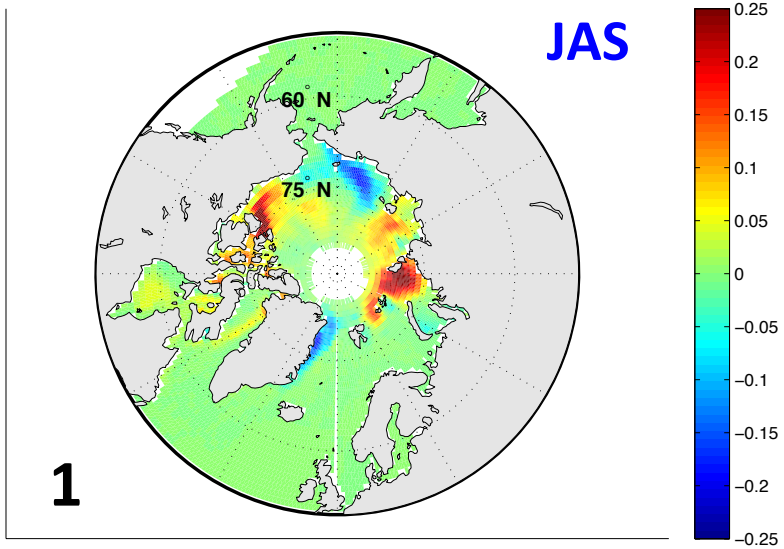
→ Euclidean distance (subsequently Minkowski metric)

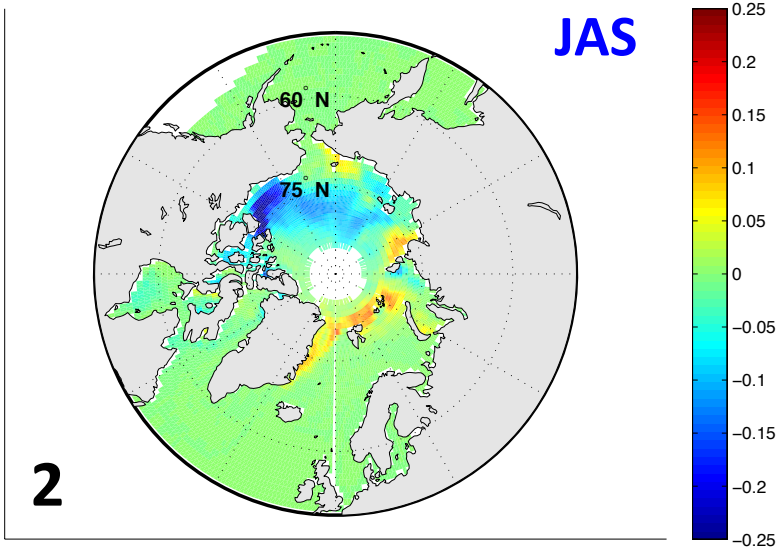
→ Further connection to self-organizing maps (SOM) = neural network-based cluster analysis

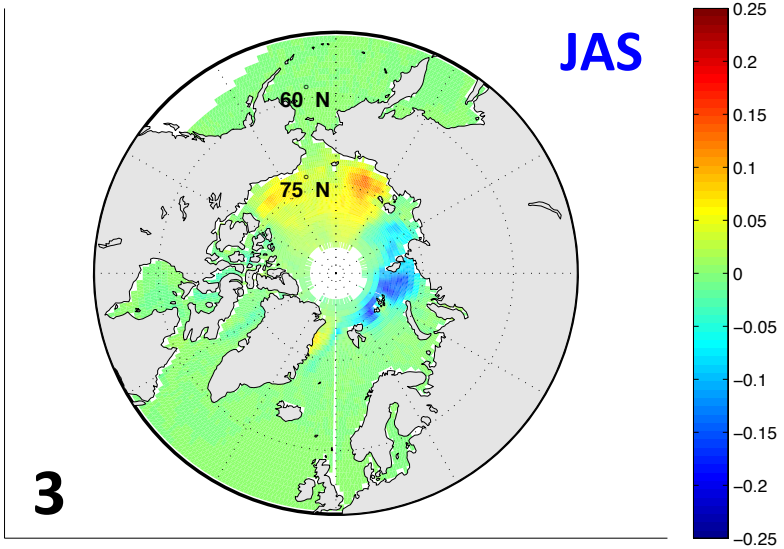
→ What is the appropriate K?

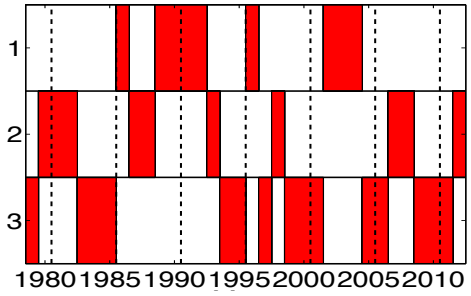
→ Statistically distinguishable clusters: Monte Carlo resampling or false discovery rate approach

- **NSIDC sea ice concentration anomaly (from 1981-2010 climatology)**



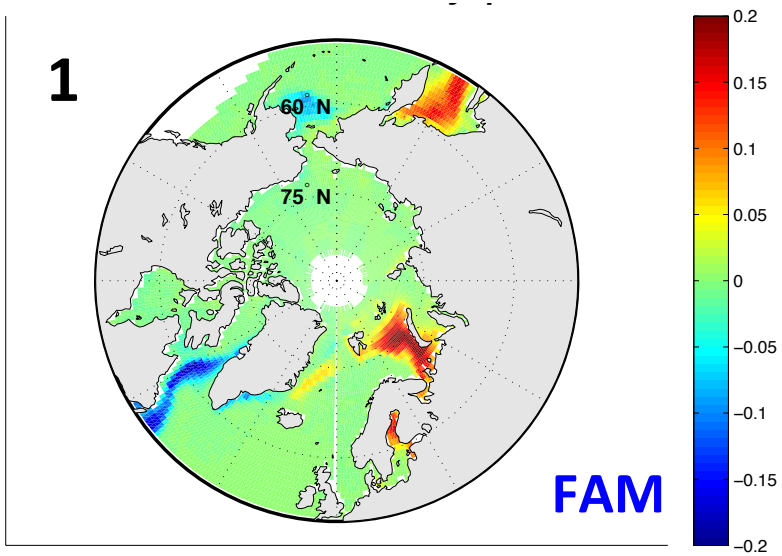


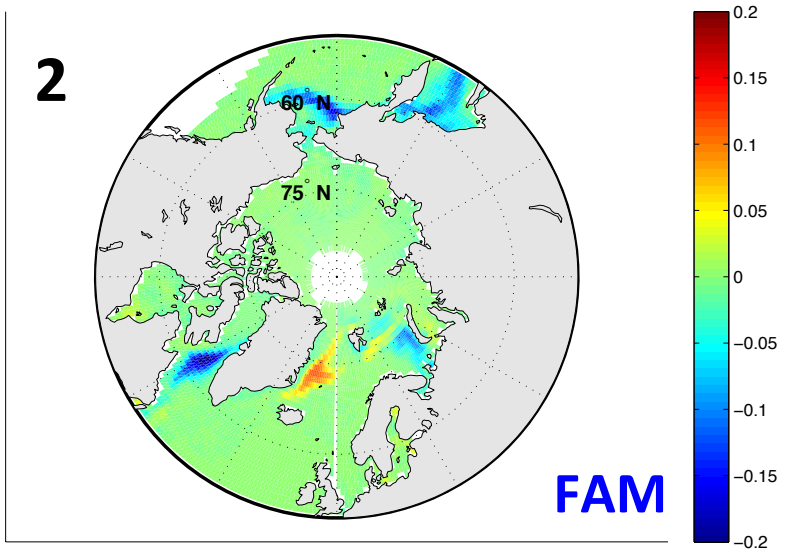


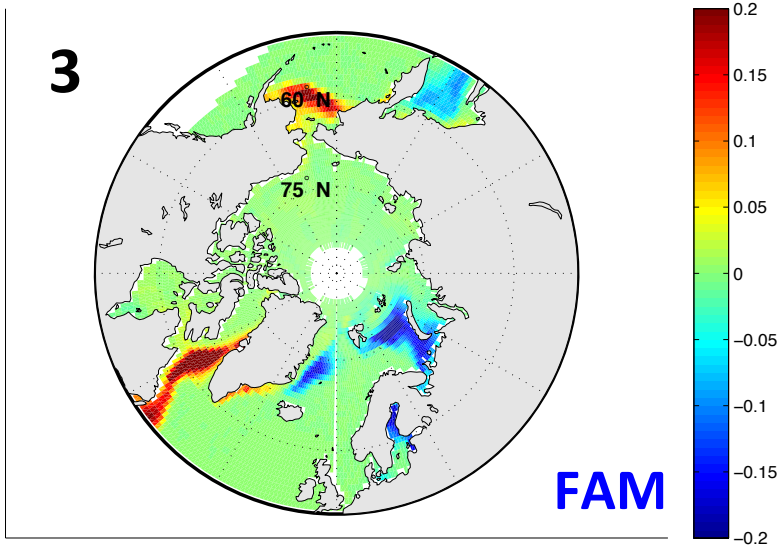


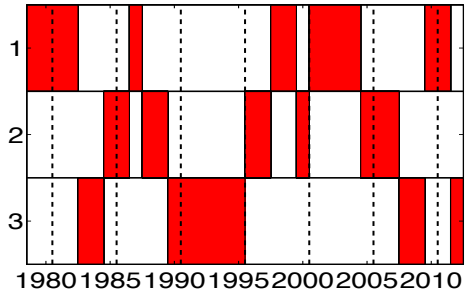
JAS K-means cluster patterns, and their occurrence time series, of **detrended anomalies** of NSIDC sea ice concentration (1979-2012)

FAM K-means cluster patterns, and their occurrence time series, of **detrended anomalies** of NSIDC sea ice concentration (1979-2012)



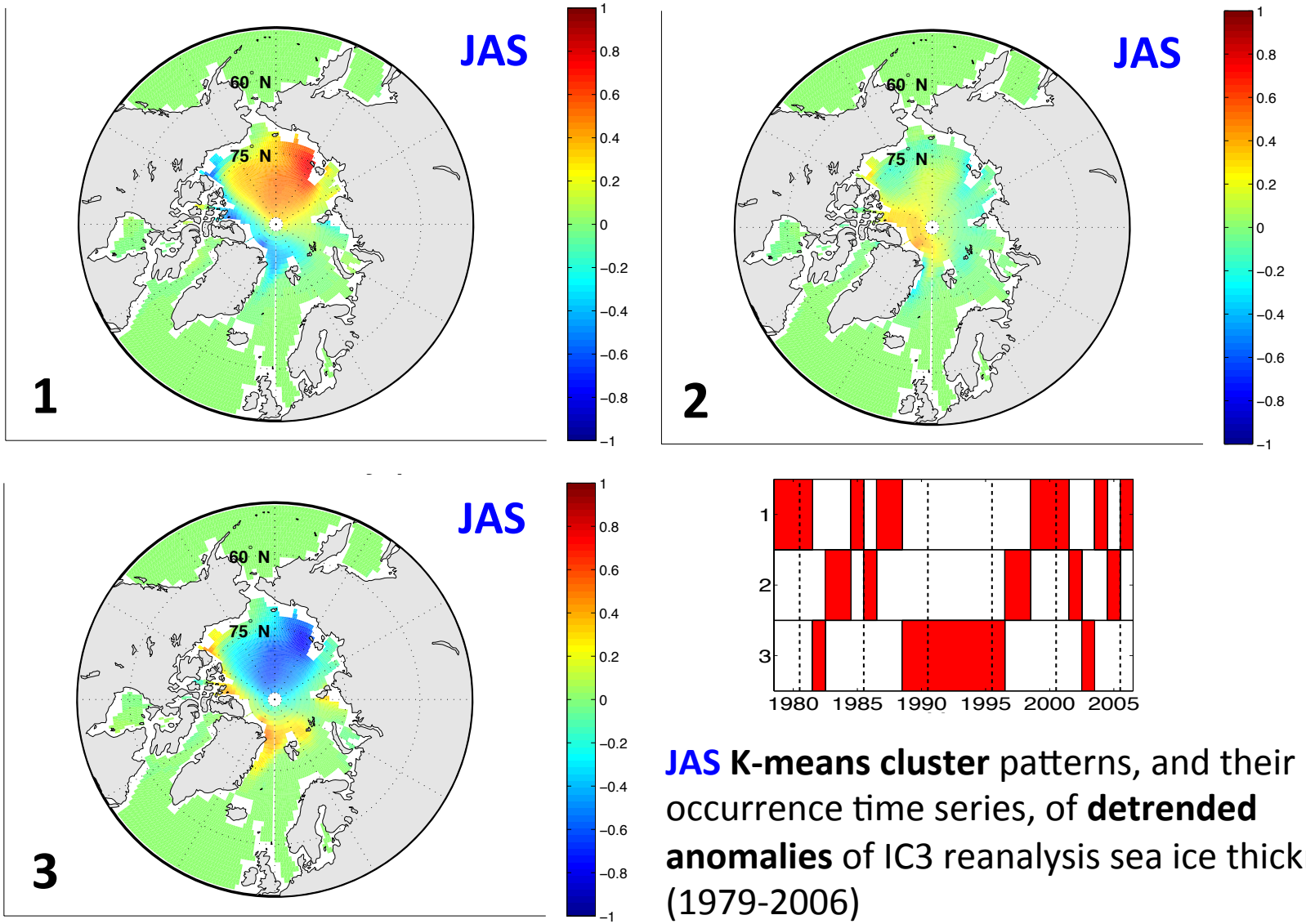






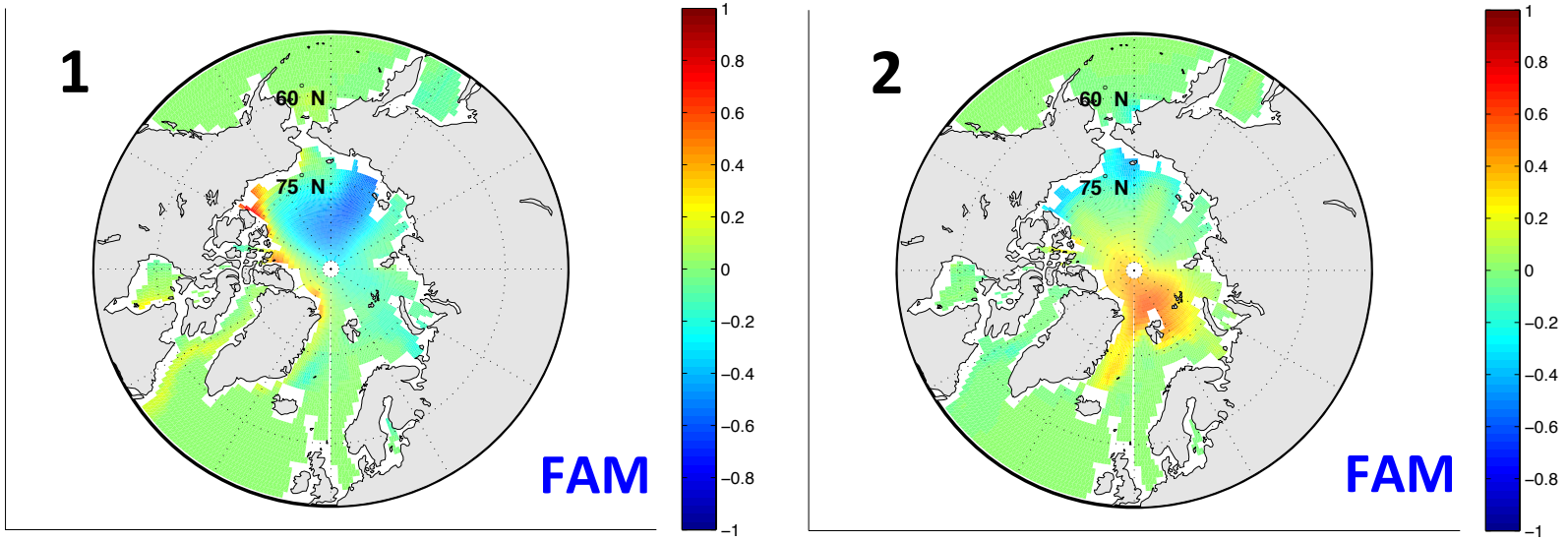
1st dipole between Labrador Sea and Greenland + Barents Sea, and 2nd dipole between Bering Sea and the Sea of Okhotsk => synchroneous variability of sea ice concentration in the Atlantic and Pacific

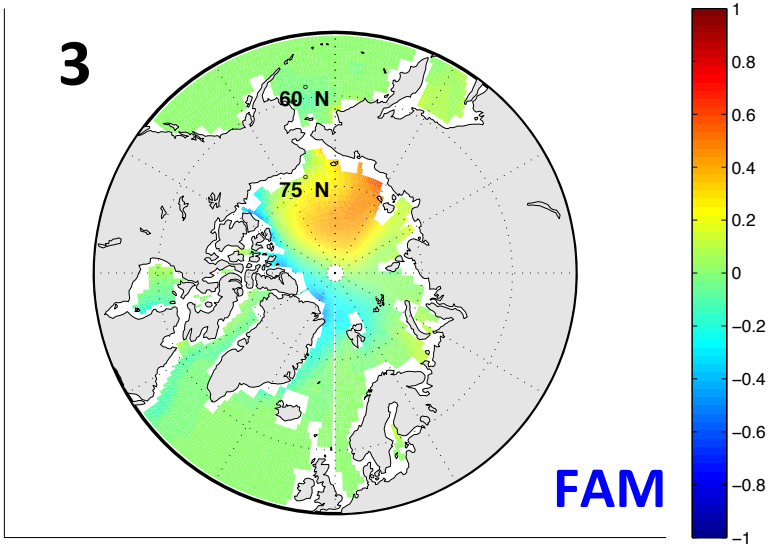
● IC3 reanalysis (NEMO3.2 + LIM2) sea ice thickness anomaly (from 1981-2006 climatology)

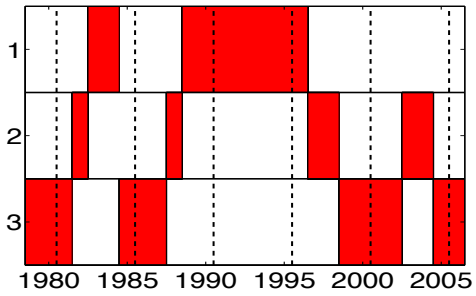


JAS K-means cluster patterns, and their occurrence time series, of **detrended anomalies** of IC3 reanalysis sea ice thickness (1979-2006)

FAM K-means cluster patterns, and their occurrence time series, of **detrended anomalies** of IC3 reanalysis sea ice thickness (1979-2006)







Melt and growth seasons are reflected in sea ice thickness patterns with roughly dipole structure between the Atlantic and Pacific gateways

→ the next step: composite maps of SLP, SST, …

● Conclusions, future directions and events

- IC3 is a provider of sea ice initial conditions for seasonal to decadal predictions for the EC-Earth consortium → evident improvements in forecast skills over the Arctic arise from observation-based sea ice IC
- 2012 record low seems primarily due to sea ice IC, or memory, and warm surface conditions
- Aim 1: Furthering understanding of seasonal to decadal, and longer changes in Arctic climate and its impact on lower latitudes
- Aim 2: Build dynamical and statistical prediction capabilities on seasonal to decadal timescales of the Arctic sea ice and climate, and the European and Mediterranean climates
- Arctic sea ice dynamics, modelling and prediction workshop at IC3 in Barcelona on December 12, 2012 (and the rest of the week)
- Polar and non-polar connections meeting in Barcelona in late 2014 or early 2015 (sponsored by WWRP and WCRP of WMO and UNESCO)